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Determination of Power-Flux-Density of Mobile Transceiver Stations in Kagara, Rafi LGA, Niger State

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ABSTRACT

The rapid expansion of mobile transceiver stations across urban and rural communities in Nigeria has raised growing concerns regarding the potential health impacts of continuous exposure to radiofrequency (RF) radiation. Often, these stations are located near residential areas and public facilities without thorough assessment of associated risks. This study evaluated the power flux density of RF emissions from mobile transceiver stations in Kagara, Rafi Local Government Area, Niger State, to assess compliance with safety limits established by the International Commission on Non-Ionizing Radiation Protection (ICNIRP). Signal strengths from all mobile network operators in the study area were measured using an RF Strength Meter (Model 480836) along accessible routes, with corresponding distances and coordinates recorded using a Global Positioning System (GPS) device. Analysis revealed significant spatial variability in power flux density, influenced primarily by environmental factors such as terrain, buildings, and vegetation. Despite these fluctuations, the maximum observed power flux density was 66.79 mW/m², substantially below the ICNIRP guideline of 4,500 mW/m² for 900 MHz signals, indicating that public exposure levels are within internationally accepted safe limits.

Keywords:
Non-ionizing Radiation,
Mobile Transceiver,
Electromagnetic Radiation,
Power Flux Density.

INTRODUCTION

Over the past few decades, mobile telecommunications have undergone rapid growth, resulting in a substantial increase in the deployment of mobile transceiver stations, commonly referred to as Base Transceiver Stations (BTS). These stations are central to mobile communication networks, facilitating the transmission and reception of RF signals between user devices and core network infrastructure. With growing population density and increasing dependence on mobile technology for personal, educational, social, and economic activities, the number of BTS installations has expanded significantly to ensure reliable network coverage (ITU, 2020; GSMA, 2020).

Mobile transceiver stations emit RF electromagnetic fields (EMFs), which are classified as non-ionizing radiation. Unlike ionizing radiation such as X-rays and gamma rays, non-ionizing RF radiation does not possess sufficient energy to ionize atoms or molecules. Nevertheless, concerns have arisen regarding the potential health implications of prolonged RF exposure, particularly when BTS are situated near schools, hospitals, residential areas, and other sensitive locations (ICNIRP, 2011; ICNIRP, 2020).

The increasing density of BTS installations in urban and suburban areas has intensified scrutiny over whether emitted RF levels comply with international safety limits. Although RF radiation is non-ionizing, it can cause biological effects through thermal mechanisms (i.e., tissue heating). Additionally, some studies suggest the possibility of non-thermal biological effects occurring without measurable temperature increases, though the significance of such effects remains under scientific debate (Kumar et al., 2021).

In 2011, the International Agency for Research on Cancer classified RF electromagnetic fields as "possibly carcinogenic to humans" (Group 2B), citing increased risks for glioma associated with wireless phone use. While this classification does not establish causality, it emphasizes the need for continued research and monitoring of human RF exposure, particularly in environments with continuous and close-range exposure such as areas surrounding BTS (WHO/IARC, 2011).

In Nigeria, regulatory oversight and public awareness regarding RF exposure are limited. The Nigerian

Communications Commission (NCC) provides guidelines for BTS siting (NCC, 2019), including recommended minimum distances from residential buildings. However, enforcement is often inconsistent, and BTS are sometimes installed within close proximity to homes, schools, religious institutions, and marketplaces. This situation raises concerns about adherence to safety protocols and the potential long-term health implications for nearby residents.

Furthermore, public understanding of RF radiation is generally low. Many community members are unaware of actual exposure levels, and opposition to BTS installation often arises from perception rather than evidence. The scarcity of empirical data on local RF exposure contributes to misinformation, anxiety, and distrust, complicating efforts to reconcile technological development with public health considerations (Foster & Glaser 2007; Kumar *et al*., 2021).

Globally, several regulatory agencies, including the International Commission on Non-Ionizing Radiation Protection (ICNIRP), have established exposure limits for RF radiation. These guidelines are intended to protect all members of the population, including vulnerable groups such as children and the elderly, and are based on rigorous scientific assessment of thermal effects. Compliance with these limits requires not only adherence to recommended siting protocols but also ongoing monitoring and enforcement, which may be challenging in regions with limited regulatory capacity (Andrews *et al*., 2014; FFC, 2021).

Given these challenges, localized and systematic assessments of RF radiation exposure are essential, particularly in communities where BTS are located near daily human activities. Such evaluations provide empirical data on actual exposure levels, identify potential hotspots, and verify compliance with international safety standards. These studies are also critical for informing evidence-based policy decisions, guiding urban planning, and educating the public on RF safety.

Additionally, RF exposure is a socio-political and environmental issue. Urbanization, high population density, and the competitive pressures of the telecommunications industry can complicate adherence to siting standards. Telecom providers may prioritize network coverage and market expansion over public safety. Without independent monitoring and enforcement, this can lead to noncompliance with safety distances and other protective measures (Bhatt *et al*., 2016; Ali *et al.,* 2021).

This study aims to address these gaps by empirically measuring RF radiation levels near BTS installations in Kagara, Rafi LGA, Niger State. The findings are compared against international safety limits to determine whether current RF emissions pose a risk to residents, thereby contributing to the evidence base necessary for informed policy-making and safer infrastructure deployment in Nigeria.

Numerous studies have been conducted across Nigeria to assess RF radiation levels from BTS masts, providing a valuable context for this research. In a study conducted in Geidam, Yobe State, Geidam and Kassim (2021) measured the electric field intensity and power density from seven BTS antennas. Their results showed that the highest measured power density was 1.265 mW/m², a value significantly below the international safety limits. They concluded that the radiation levels did not pose an adverse health risk but recommended routine assessments due to technological upgrades.

Similarly, Elechi *et al. (*2019) evaluated the SAR and power density from five BTS facilities in Port Harcourt, Rivers State. They found that the average SAR values ranged from 0.0037 W/kg to 0.0084 W/kg, and the power density was between 1.5183 W/m² and 9.5083 W/m². These values were well within the limits set by the International Commission on Non-Ionizing Radiation Protection (ICNIRP), leading to the conclusion that there was no significant health risk to residents in the vicinity. In Gusau, Zamfara State, Maduka *et al. (*2019) measured power densities from MTN, Airtel, and 9mobile masts. The highest recorded mean power density was 45.60 mW/m², which is substantially below the ICNIRP standard limit of 4.5 W/m² for the 900 MHz system. The study concluded that the exposure levels were low and did not pose a significant health risk.These studies consistently show that in the specific locations measured, the RF radiation levels from mobile base stations were below the internationally accepted safety limits. However, they also highlight the importance of localized measurements, as levels can fluctuate based on the number of antennas, their power, and environmental factors (Geidam & Kassim, 2021).

MATERIALS AND METHODS

Measurements of power flux density associated with electromagnetic radiation emitted from mobile transceiver stations located in Kagara, Rafi Local Government Area of Niger State were conducted using an Extech RF EMF Strength Meter (Model 480836). In addition, a Global Positioning System device (GPS 72 Personal Navigator) was utilized to determine the line-of-sight distances as well as the geographical coordinates (latitude and longitude) of the measurement locations as shown in Figure 1 and 2.

Figure 1: Extech RF EMF Strength Meter Level (480836 Meter)

Figure 2: Global Positioning System (GPS 72 – Personal Navigator)

Study Area

Kagara is a community in Niger State, the headquarters of the Rafi Local Government Area with population of 28,942 people and area of 1.616 km² (Figure 3). The Kagara Emirate is a traditional state with a first-class stool. Kagara is part of the Niger East Senatorial district, and is the seat of the Kagara Emirate. As the LGA headquarters, it is a key administrative center in Niger East Senatorial District. The climate is tropical wet-and-dry, with hot temperatures peaking in March–April (Wikipedia).

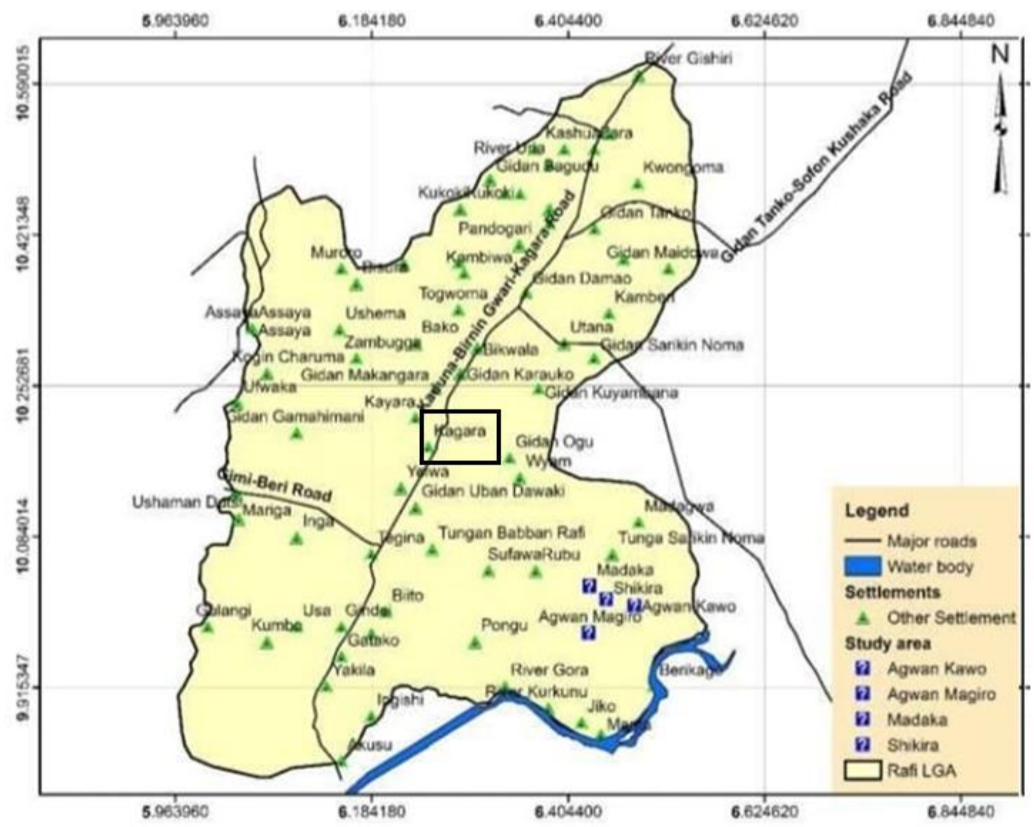

Figure 3: Map of Rafi LGA Showing Kagara

Data Collection and Analysis

One of the Base Transceiver Station (BTS) sites was designated as the reference point for the measurement exercise. The power flux density was measured by orienting the Extech RF EMF Strength Meter (Model 480836) directly toward the source of the radio-frequency (RF) radiation. Measurements were conducted at intervals of 100 m from each base station in order to examine the variation of radiation levels with distance. A Global Positioning System device (GPS 72 – Personal Navigator) was further employed to determine the corresponding distances from the base of the transmitting antenna as well as the geographical coordinates (latitude and longitude) of each measurement location.

The data obtained from the field measurements were processed and analyzed using a spreadsheet application, Microsoft Excel, installed on a personal computer. In addition, Surfer 16 software was utilized to generate spatial representations and coverage maps of the mobile network within the study area. In order to minimize the influence of body interference during data acquisition, the RF meter was held at arm's length while measurements were taken. Each reading was allowed to stabilize for approximately two minutes before being recorded to ensure reliability and accuracy of the measurements. Furthermore, necessary precautions were taken to avoid interference from extraneous sources such as active mobile phones, moving vehicles, and nearby electronic devices, which could potentially affect the measurement results.

Estimation of Power and Energy Exposure to Human Body

The potential power exposure to human body from the BTS was estimated by modeling a human body as a cylinder with an average height of 1.71 m (NBRRI Report 10) and waist circumference of 0.951 m (Australian Bureau of Statistics, 2022).

The curved surface area (CSA) of human body was computed as:

$$CSA = waist\ circumference \times height = 1.62621\ m^2 \quad (1)$$

The power exposure was calculated as:

$$P_{exposure} = P_d \times CSA \quad (2)$$

$$P_{exposure} = 1.62621 P_d \quad (3)$$

where P_d is the power flux density in W/m^2. This gave an estimate of potential radiation exposure on the human body in the studied environments.

To estimate the cumulative energy exposure in joules, the power was multiplied by the time of exposure, *t*, in seconds

$$Energy_{exposure} = P_{exposure} \times t \quad (4)$$

RESULTS AND DISCUSSION

The results obtained from this study indicate that the measured radio-frequency (RF) power flux density within the study area are substantially lower than the exposure limits recommended by the International Commission on Non-Ionizing Radiation Protection (ICNIRP) for the general public. As illustrated in Figures 4 to 6, all recorded values fall well within internationally accepted safety thresholds, suggesting that RF emissions from the investigated base transceiver stations do not present a significant environmental or public health concern within the study location.

A clear trend observed in the results is the gradual reduction in signal strength with increasing distance from the base station. Consequently, the power flux density also decreases as the separation from the transmitting antenna increases. This behaviour is consistent with the theoretical principles governing electromagnetic wave propagation, particularly the inverse relationship between signal intensity and distance from the source. As electromagnetic waves propagate outward, their energy becomes distributed over a larger area, leading to attenuation of the measured field strength.

Despite this general trend, the attenuation pattern was not entirely uniform. The graphical analysis revealed noticeable fluctuations characterized by intermittent peaks and troughs at different measurement distances. These variations can be attributed to several environmental and physical factors present within the study area, including buildings, vegetation, terrain irregularities, and other structural obstructions that influence signal reflection, diffraction, and scattering. In addition, the observed increase in signal strength at certain points can be explained by proximity to neighbouring mobile base stations, which contribute additional RF signals that affect the overall measured values. Figure 7 further illustrates the spatial distribution of power flux density across the coverage area, highlighting the variability of RF exposure within the environment.

A comparison of the measured data with the safety guidelines established by the International Commission on Non-Ionizing Radiation Protection (ICNIRP, 2020) indicates that the highest recorded power density was 66.79 mW/m². This value is significantly lower than the ICNIRP recommended exposure limit of 4,500 mW/m² for frequencies around 900 MHz. In practical terms, the maximum measured value is approximately forty-one times lower than the permissible limit for public exposure. This substantial margin below the regulatory threshold provides strong evidence that the RF radiation levels within the study area remain within acceptable safety standards.

Furthermore, the estimated energy exposure from the mobile base stations for an average adult was calculated to be approximately 595.9 kJ per hour and 14,301 kJ per day. Although these values quantify the level of environmental RF energy present, they remain within ranges considered safe according to international radiation protection standards. Therefore, the cumulative exposure associated with the operation of mobile communication infrastructure in Kagara does not appear to pose any immediate or significant health risk to residents.

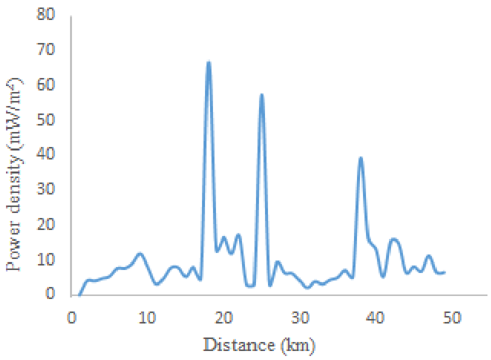

Figure 4: Power Flux Density

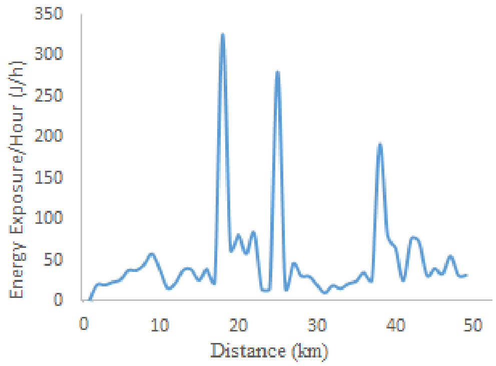

Figure 5: Energy Exposure/Hour

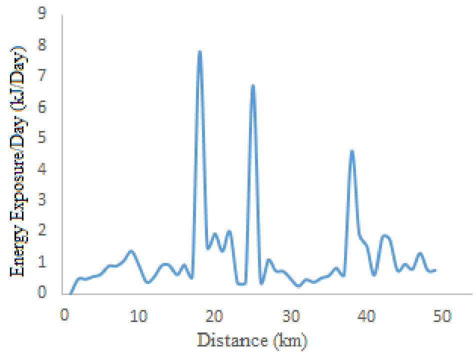

Figure 6: Energy Exposure/Day

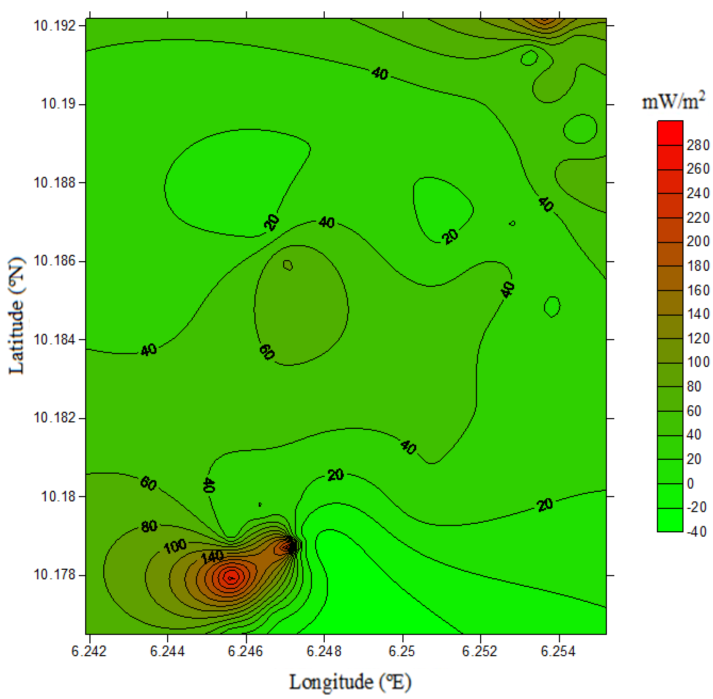

Figure 7: Power Flux Density Distribution Across the Signal Coverage Area

CONCLUSION

Based on the field measurements and the subsequent analysis conducted in this study, it can be concluded that human exposure to radio-frequency (RF) radiation from mobile transceiver stations within the study area remains well within internationally accepted safety standards

adopted by many countries, including Nigeria. The maximum recorded power density was 66.79 mW/m², which is considerably lower than the maximum permissible exposure limits recommended by organizations such as the International Commission on Non-Ionizing Radiation Protection (ICNIRP).
These findings indicate that members of the public in the study area are not exposed to RF radiation at levels capable of producing acute thermal effects. According to the current scientific understanding of RF exposure and its thermal impacts, the radiation levels associated with the examined mobile base stations do not present any immediate health risk to individuals residing within the vicinity. Nevertheless, it is important to emphasize the need for continued public awareness and scientific monitoring, particularly regarding the possibility of long-term exposure to low-level radiation. Although current evidence suggests compliance with established safety standards, the cumulative effects of prolonged exposure remain an area of ongoing scientific investigation and therefore warrant sustained research attention.

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